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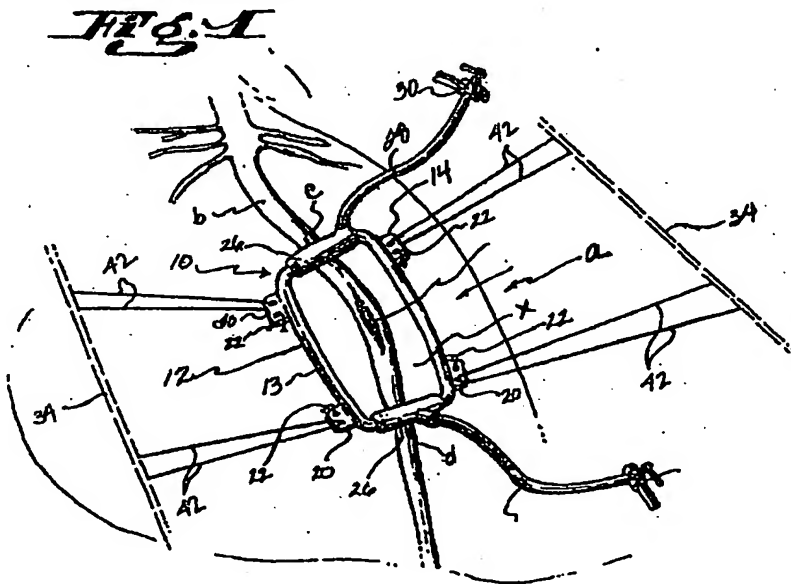
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### (54) Epicardial immobilization device

(57) A device and method is described for immobilizing a portion of the epicardium without interrupting the beating of the heart, which includes a frame provided with means for temporarily anchoring the frame to the epicardium and occlusion means in the

form of an expandable member which, upon inflation, temporarily occludes the passage of blood through the vessel or vessels in the operational field defined by the frame.



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## Description

### BACKGROUND OF THE INVENTION

#### Field of the Invention

This invention generally relates to devices used and methods employed in connection with surgical procedures affecting the heart and, more specifically, relates to an epicardial immobilization device and method of use, the principal purpose of both being to reduce the movement of, or to immobilize, a region of the cardiac epicardium during surgery to permit the heart to be operated on while it is beating.

#### Description of the Related Art

Surgical treatment and repair of vital organs, especially of the heart, requires a high degree of precision on the part of the physician and surgical team, and such precision heretofore has been difficult to achieve when the organ is functioning, because movement of the organ can compromise the accuracy and relative safety with which an operation successfully can be accomplished. Accordingly, and with respect to cardiac cases in particular, it has been conventional to temporarily stop the heart from functioning to effectively immobilize it while an operation is being performed. Most commonly, this is accomplished by diverting blood flow to the heart through the use of an external pump, such as with a device referred to as a "heart-lung machine," which is intended to substitute for the function of the organ so that blood can be sufficiently oxygenated and circulated through the body during surgery. The heart thus effectively will be immobilized, and the physician and the surgical team can render treatment on particular parts of the heart, or the vessels supplying or leading to or from it, with greater precision than would be possible if the heart were beating.

Clearly, though, it easily is appreciated that diverting the function of a vital organ to an artificial mechanical substitute can entail significant trauma under any circumstances and, depending on the overall condition of a particular patient, the prospect of such trauma can be such as to contraindicate life-sustaining or quality-of-life-enhancing treatment. Thus, there has been an effort to develop surgical techniques which obviate the need to resort to a heart-lung replacement pump, so as to allow an operation for treatment or repair of the heart or of its associated vessels while the heart is functioning and beating. The class of patients for which such techniques have been deemed appropriate, however, has been limited by the precision implicated by a particular procedure, because of the challenges inherently presented by a beating heart. Continuous movement of the heart renders any surgical operation performed on it or its associated vessels more complicated and more difficult than would be experienced if the organ were non-

functional and, hence, effectively immobilized. Accordingly, use of techniques which involve surgical treatment of a beating heart has been limited.

One device that has been employed to immobilize the beating heart during surgery comprises a supporting ring in the shape of an open "O" and having an attached rigid arm. The supporting ring includes a base provided with a plurality of vacuum cups that are connected to a pneumatic circuit. The vacuum cups, when supplied with a suctioning force, are used to temporarily secure the device to the epicardium. Experience with this device has been less than optimum, insofar as post-surgical lesions and hematomas have been detected that are associated with the areas of the epicardium to which the vacuum cups were attached. It also is of some significance that this device is relatively expensive to use.

When an object of the surgery is treatment of the vessels of the heart muscle (e.g., the coronary arteries), another complication often is encountered due to the presence in the vasculature of occlusions, such as atheromatous plates or other restrictions, that result from atherosclerosis or another disease or condition known to cause vascular obstruction. Because these vessels carry blood (except when totally occluded), blood flow through the vessels must be curtailed while the surgery is being performed, such as operations to suture venous or arterial bridges, in order to prevent obscuring the surgeon's view of the operational field.

In the past, blood flow through the vessels of interest temporarily has been prevented through the use of ligatures, sutures or clamps which, when tightened, close off the vessel. When occluded vessels, such as coronary arteries exhibiting atheromatous plates, are involved, great care must be taken in choosing the site along the vessel at which to place a ligature, suture or clamp. This is the case because, if the compression associated with the tightening of such a ligature, suture or clamp is applied to an area in the vessel that is affected by an occlusion, the tightening force can cause the occlusion to fracture. Such fracture then might result in the partial dislodgement of the occlusion when the compressing device is removed; the dislodged portions can cause further obstructions to blood flow, such as clot formation, or other problems as the portions move through the vasculature of the patient.

In an attempt to reduce the risk that the ligatures, sutures or clamps used to temporarily prevent blood flow will cause the fracture of atheromatous plates, before placing the compressing devices, surgeons have relied on palpating the vessels before the ligatures, sutures or clamps are positioned, in order to make sure that the intended site of placement is flexible rather than rigid, which would be the expected condition of the vessel if it were characterized by an occlusion. Palpation is effective for detect plates when the plates are present in the epicardial, or outer, surface of the lumen of a vessel, but is a less effective technique when the plates are dis-

posed in the vessel laterally. Palpation is not an especially useful method of locating plates when the same are present in the endocardial, or inner, surface of the vessel lumen.

The devices to temporarily prevent blood flow in the vasculature of interest, however, commonly have been applied to regions of the vessels that are more distal to the heart than is optimum, owing to the fact that presence of atheromatous plates is more difficult to discern in those regions.

What has been needed, then, and what heretofore has been unavailable is an apparatus and method which permit a beating heart to be held effectively immobile while a surgical operation is being performed while concurrently allowing the operating field to be kept free of obscuring blood with a reduced risk of dislodging vascular occlusions as a result of the temporary prevention of blood flow through the vessels supplying the heart. The present invention satisfies these needs.

### SUMMARY OF THE INVENTION

The present invention is directed to a device and method for effectively immobilizing the heart within the confines of a particular, defined operational field during surgery while simultaneously temporarily disrupting the passage of blood through the vessel or vessels circumscribed by the operational field so defined, thus permitting surgery to be performed on the vessel(s) free of an obstructed view. A device according to the invention includes a frame provided with a plurality of anchoring means with which to anchor the device to the epicardium. When considered appropriate, and to further secure the frame to the epicardium, connections to the epicardium can be accomplished through apertures that are provided in the anchoring means, or by way of a structure affixed to the base of the frame. One or more expandable members are disposed on opposing sides of the frame, which, when inflated, prevent(s) the flow of blood through the region of the vessel or vessels in the operational field circumscribed by the frame. The frame further can be provided with means for attaching it to an auxiliary support, when enhanced immobilization of the epicardium is deemed desirable. The frame also can be characterized by an opening or outlet passage for each vessel to be repaired.

In use, the frame of the device is positioned about the vessel or vessels to be treated by surgery, and anchored by the anchoring means. When deemed advantageous, connections to the epicardium can be made by the connecting means. The expandable member(s) then is (are) inflated to temporarily occlude the target vessel or vessels at the edges of the operational field defined by the frame, so that surgery can be carried out without blood obscuring the operational field. If deemed necessary, the immobilizing effect of the frame can be augmented by connecting it to a stationary auxiliary support.

These and other features and advantages of the present invention will become apparent from the following detailed description of the preferred embodiments which, when taken in conjunction with the accompanying drawings, illustrate by way of example the principles of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of one embodiment of an epicardial immobilization device of the invention;

FIGURE 2 is a top plan view of an alternate embodiment of the invention;

FIGURE 3 is a side perspective view of the embodiment of FIG. 2;

FIGURE 4 is a perspective view of an alternate embodiment of the invention;

FIGURE 4a is a side elevational view of the embodiment of FIG. 4, illustrating a connecting means comprising hooks;

FIGURE 5 is a perspective view of an alternate embodiment of a device of the invention illustrating a plurality of attachment means for an auxiliary support (depicted schematically);

FIGURE 6 is a perspective view of an alternative embodiment of a device of the invention illustrating a single attachment means for an auxiliary support (depicted schematically).

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the apparatus according to the present invention can be described by reference to Figure 1. The epicardial immobilization device (10) comprises a substantially rectangular frame (12) formed from a malleable or flexible material, the frame having a body (13) that is provided with means (14) for anchoring the frame to the epicardium (a) and two soft expandable members (16) which, upon inflation, function to temporarily prevent blood flow in the regions of the coronary vessel or vessels (b) circumscribed by the frame. It is contemplated that the body of the frame further might be provided with one or more openings which serve as an outlet passage or outlet passages for the vessel(s) under repair.

The frame is characterized by four anchoring means (14), in the form of earlets or tabs (18) projecting outwardly from the frame, each of which earlet or tab is provided with one or more aperture(s) (20) adapted to receive connections (22) to the epicardium. The earlets or tabs (18) preferably are positioned near the four corners comprising the substantially rectangular frame (12). It is contemplated that other embodiments of the invention might be characterized by variations in the placement or configuration of the earlets or tabs (20). For example, in FIG. 2, the four earlets or tabs (20) each

have two lobes, and are disposed at the four corners of the substantially rectangular frame (12). Likewise, embodiments characterized by a greater or lesser number of anchoring means (14) are envisioned, although at least three such anchoring means is deemed necessary. The embodiment illustrated in FIG. 4, for example, depicts six anchoring means (14).

In one embodiment, and as best illustrated in FIG. 4a, epicardial connection means (22) are provided to further secure the frame to the heart. The connection means comprise a plurality of books (24), which extend from a supporting base. The supporting base is affixed to the body (13) of the frame (12), rather than to a particular one of the anchoring means (14).

On two of the opposing sides of the frame, expandable members (16) are mounted. Each expandable member is provided with a tubular conduit (28), which conduit is associated with an inflation valve (30).

To enhance the efficiency with which a device according to the present invention can be used in a surgical procedure, and as is best illustrated in FIG. 6, the frame (12) further is provided with means (32) for attaching the frame to an auxiliary support (34), which is held stationary in relation to the heart. The auxiliary support attachment means (32) can comprise an elongated, rigid arm (36) that projects outwardly from the frame (12) and which terminates in a connection end (38) that attaches to the auxiliary support (34).

In another embodiment according to the present invention, the frame (12) is provided with a plurality of means (32) for attaching the frame to an auxiliary support (34). Each of these attachment means (32) has a first end (44) that can be connected to the auxiliary support (34) and a second end (46) which is affixed to the frame (12). In the embodiment illustrated in FIG. 5, the plurality of attachment means (32) are shown as tensioning threads or wires, which are affixed to the frame (12) through apertures (48) that have been provided in the earlets or tabs (20) of the frame for that purpose.

When used in a surgical procedure, the apparatus according to the invention is positioned so that the malleable or flexible frame (12) rests against the epicardium (a) of the heart, to define the operational field. The soft expandable members (16) thereby are disposed against an upper and lower occlusion zone (c, d) of the target vessel or vessels.

Optionally, the epicardial connections (22) via the associated hooks (24) or otherwise connect the frame (12) to the epicardium (a). An operational field on the beating heart thus is defined by the boundaries of the frame (12), and the epicardium (a) is tensioned and held relatively immobile in relation to the rest of the heart organ, which continues to beat throughout the procedure.

When the soft inflatable member or members (16) are inflated via the tubular conduits (28) and associated inflation valves (30), the expandable members press against the vessel or vessels extending through the

operational field defined by the frame (12), thus temporarily preventing the passage of blood through the vessel or vessels in the region circumscribed by the frame. More specifically, when the expandable members are inflated, the epicardial, or outer, side of the target vessel or vessels collapses against the corresponding endocardial, or inner side. The relative softness of the balloons thus accomplishes the temporary cessation of the blood flow through the affected vasculature with far less trauma than is associated with traditional occlusion techniques (e.g., those techniques involving ligatures, sutures or clamps). Surgery to treat the vessels then can be performed, e.g., a coronary bypass operation to treat a vascular lesion.

In situations in which maximum immobilization of the operational field defined by the frame (12) is desired, the singular or plurality of auxiliary support attachment means (32) can be resorted to in order to affix the frame to an auxiliary support (34).

Following the surgery, the device according to the present invention can be cut away from the epicardium and discarded. However, and as is contemplated, if the frame (12) further is provided with an opening or outlet passage for each repaired vessel, not only can the frame be removed without cutting, but it can be preserved intact for potential future uses in other procedures.

While a particular form of the invention has been illustrated and described, it will also be apparent to those skilled in the art that various modifications can be made without departing from the scope of the invention. Accordingly, it is not intended that the invention be limited except by the appended claims.

## Claims

1. A device for effectively immobilizing the epicardium of the heart in a specific operational field and for keeping the field free of obscuring blood flow during surgery, the device comprising:

a frame for defining an operational field, said frame having a body to which are attached a plurality of anchoring means for anchoring said frame to the epicardium; and

a first expandable member disposed on a first side of said frame, said expandable members being connectable to an inflation source;

wherein, said frame can be secured to the epicardial surface by way of said anchoring means and said connecting means, and the operational field can be kept free of blood flow during surgery by inflating said expandable member to temporarily stop the passage of blood through portions of vessels within the field defined by the frame.

2. The device of claim 1, further including a second

- expandable member disposed on a second side of said frame, said second expandable member being connectable to an inflation source.
3. The device of claim 1, wherein said frame is formed from a flexible material.
  4. The device of claim 1, wherein said frame is substantially rectangular in shape.
  5. The device of claim 3, further comprising four anchoring means wherein each anchoring means is disposed approximately at a corner of said substantially rectangular frame.
  6. The device of claim 1, wherein said plurality of anchoring means comprises at least three anchoring means.
  7. The device of claim 1, wherein said plurality of anchoring means comprises four anchoring means.
  8. The device of claim 1, wherein said plurality of anchoring means comprises six anchoring means.
  9. The device of claim 1, wherein each of said plurality of anchor means is spaced approximately equidistantly from every adjacent one of said plurality of anchoring means.
  10. The device of claim 1, wherein each of said plurality of anchoring means is in the shape of an earlet.
  11. The device of claim 1 further including connecting means for connecting said frame to the epicardium.
  12. The device of claim 11, wherein each said earlet is provided with an aperture adapted to receive said connecting means.
  13. The device of claim 11, wherein each said earlet further is provided with attachment means for affixing said frame to an auxiliary support.
  14. The device of claim 13, wherein said attachment means comprises tensioning threads.
  15. The device of claim 13, wherein said attachment means comprises tensioning wires.
  16. The device of claim 1, wherein said body of said frame is provided with attachment means for attaching said frame to an auxiliary support.
  17. The device of claim 16, wherein said attachment means comprises a rigid arm that projects outwardly from said frame.
  18. The device of claim 1, wherein each of said plurality of anchoring means is in the shape of an earlet and each earlet is provided with an aperture adapted to receive connecting means for connecting said frame to the epicardium.
  19. The device of claim 1, wherein said connecting means is disposed on a base of said body of said frame.
  20. The device of claim 19, wherein said connecting means further comprises a plurality of hooks for connecting said frame to the epicardium.
  21. The device of claim 1, wherein each of said plurality of anchoring means is in the shape of an earlet wherein each said earlet is provided with attachment means for affixing said frame to an auxiliary support.
  22. The device of claim 1, wherein said body of said free further is provided with at least one opening, said at least one opening providing an outlet passage for a vessel under repair.
  23. A method for effectively immobilizing the epicardium of the heart in a specific operational field and for keeping the field free of obscuring blood flow during surgery, employing a device having a frame including a plurality of anchors means for anchoring the frame to the epicardium and at least one expandable member, disposed on the frame, which is connectable to an inflation source, the method comprise the steps of:
    - (a) positioning the frame so the frame is anchored to the epicardium by the anchoring means;
    - (b) connecting the at least one expandable member to an inflation source; and
    - (c) inflating the expandable member to discourage the passage of blood through the portion of the vasculature to be treated by the surgical procedure.
  24. The method of claim 23, further comprising the step of attaching the frame to an auxiliary support, to enhance the immobilization of the epicardium.
  25. A method for effectively immobilizing the epicardium of the heart in a specific operational field and for keeping the field free of obscuring blood flow during surgery, employing a device having a frame including a plurality of anchoring means for anchoring the frame to the epicardium, connecting means for connecting the frame to the epicardium, and at

least one expandable member, disposed on the frame which is connectable to an inflation source, the method comprising the steps of:

- (a) positioning the frame so the frame rests 5  
against the epicardium;
- (b) connecting the frame to the epicardium with  
the connecting means;
- (c) connecting the at least one expandable  
member to an inflation source; 10
- (d) inflating the expandable member to discour-  
age the passage of blood through the portion of  
the vasculature to be treated by the surgical  
procedure. 15

26. The method of claim 25, further comprising the step  
of attaching the frame to an auxiliary support, to  
enhance the immobilization of the epicardium.

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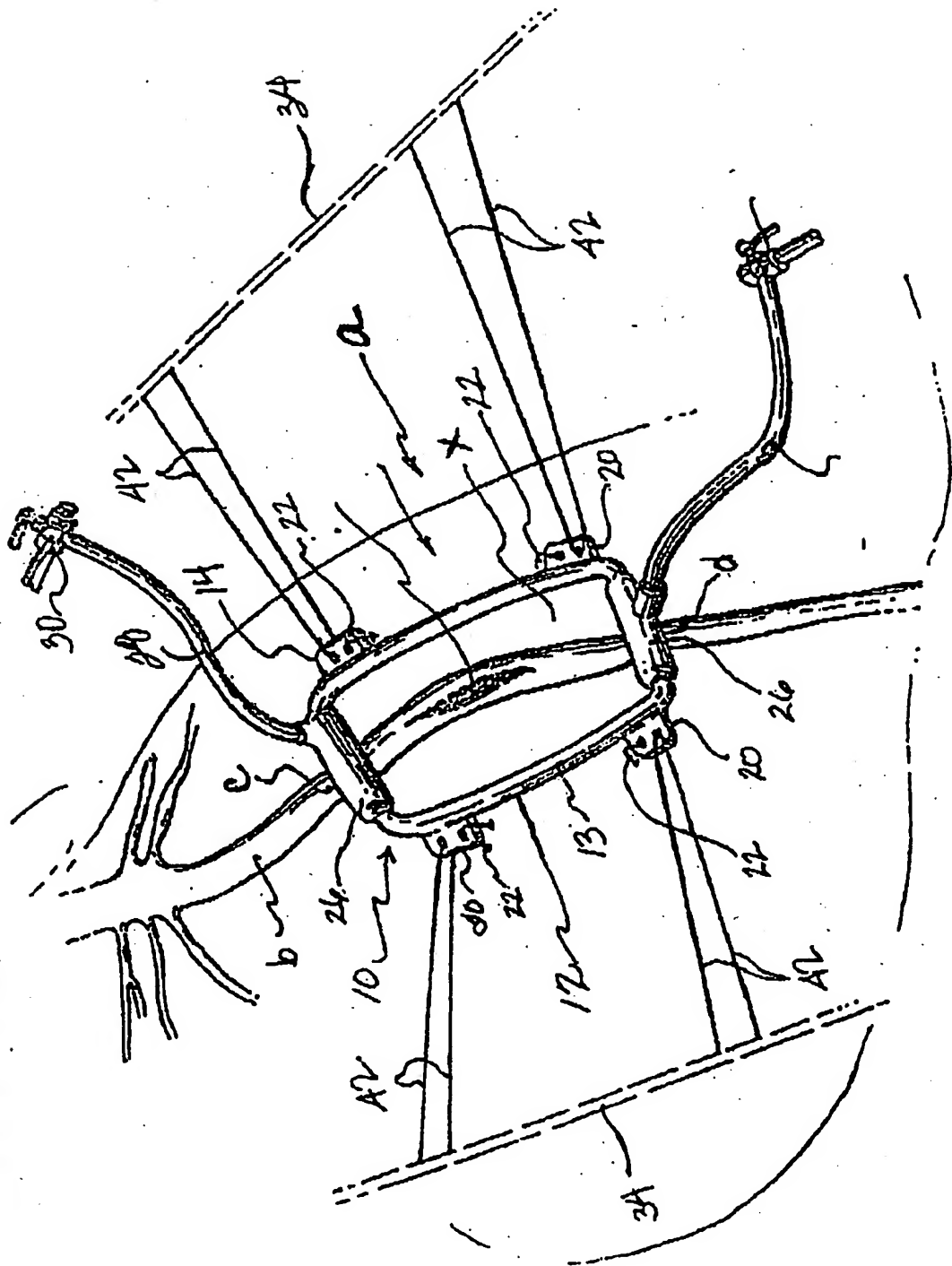
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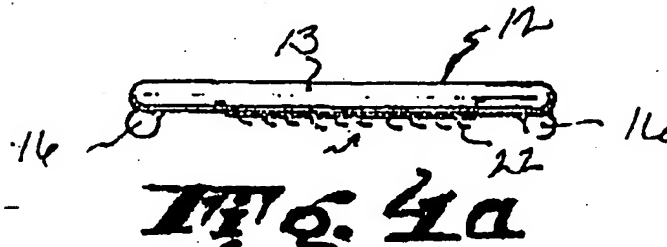
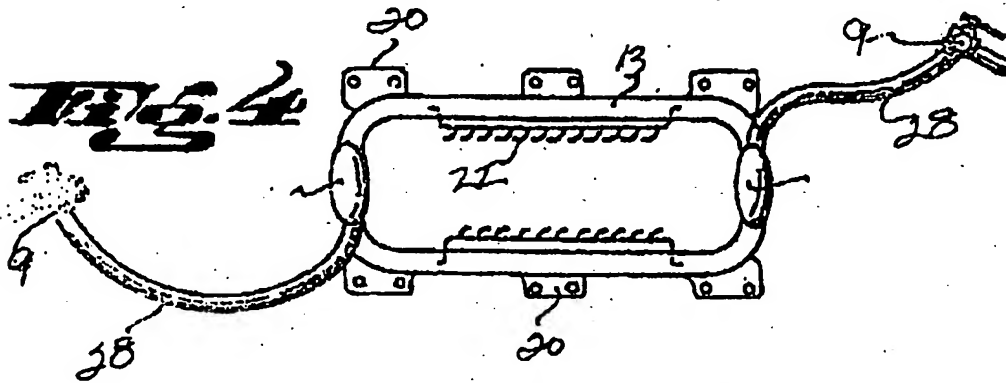
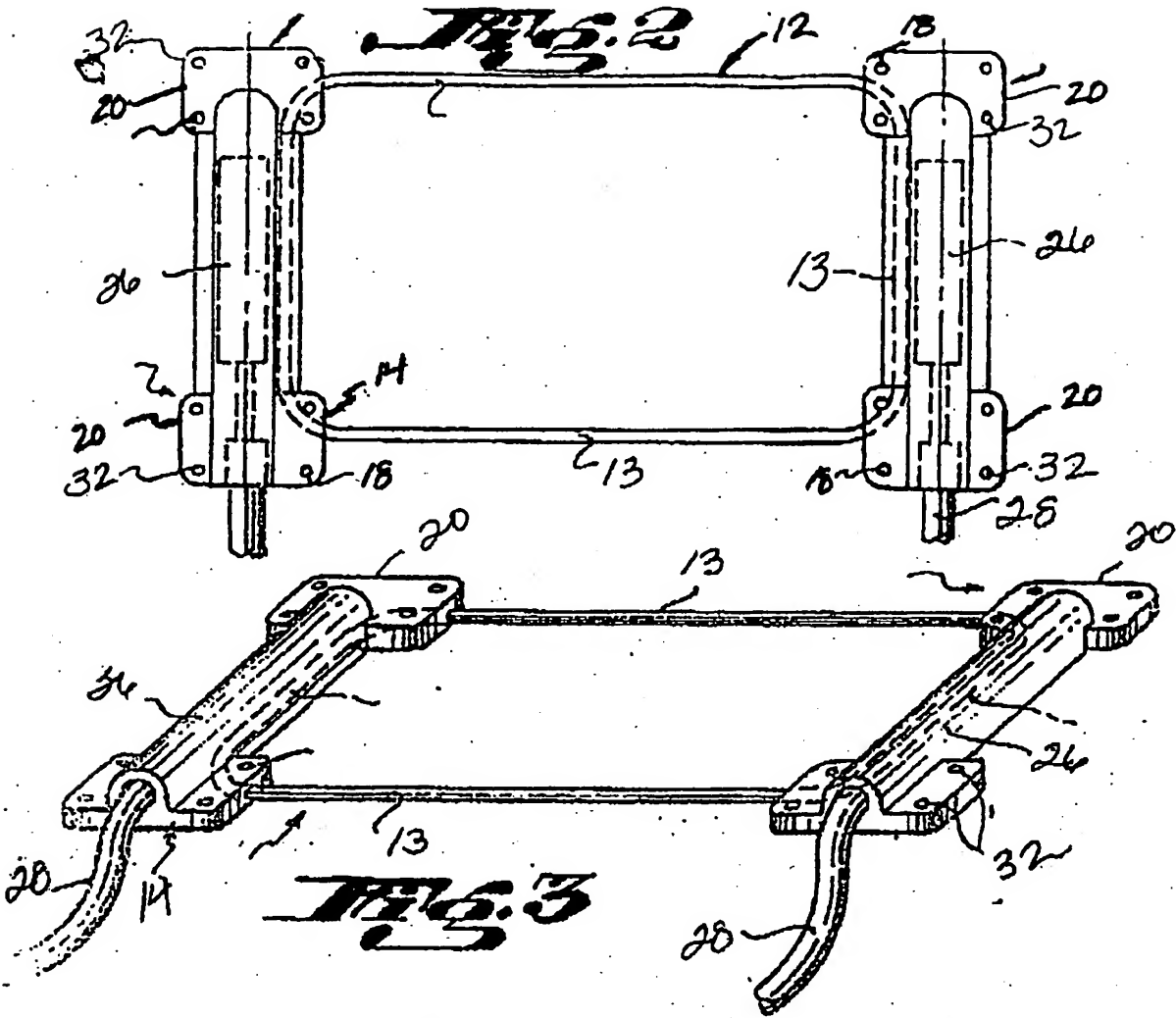
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FIG. 1







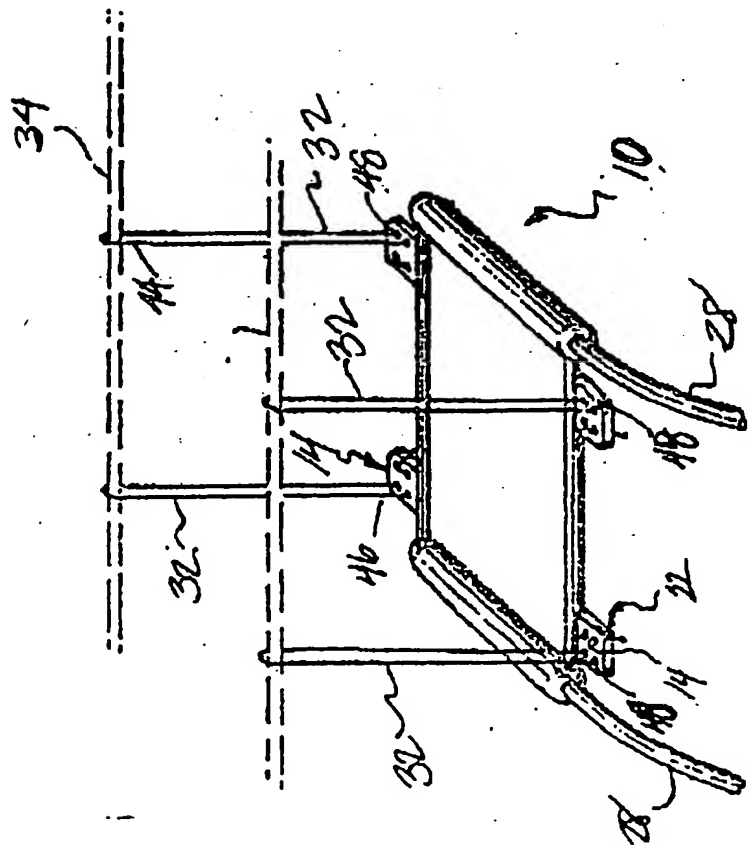
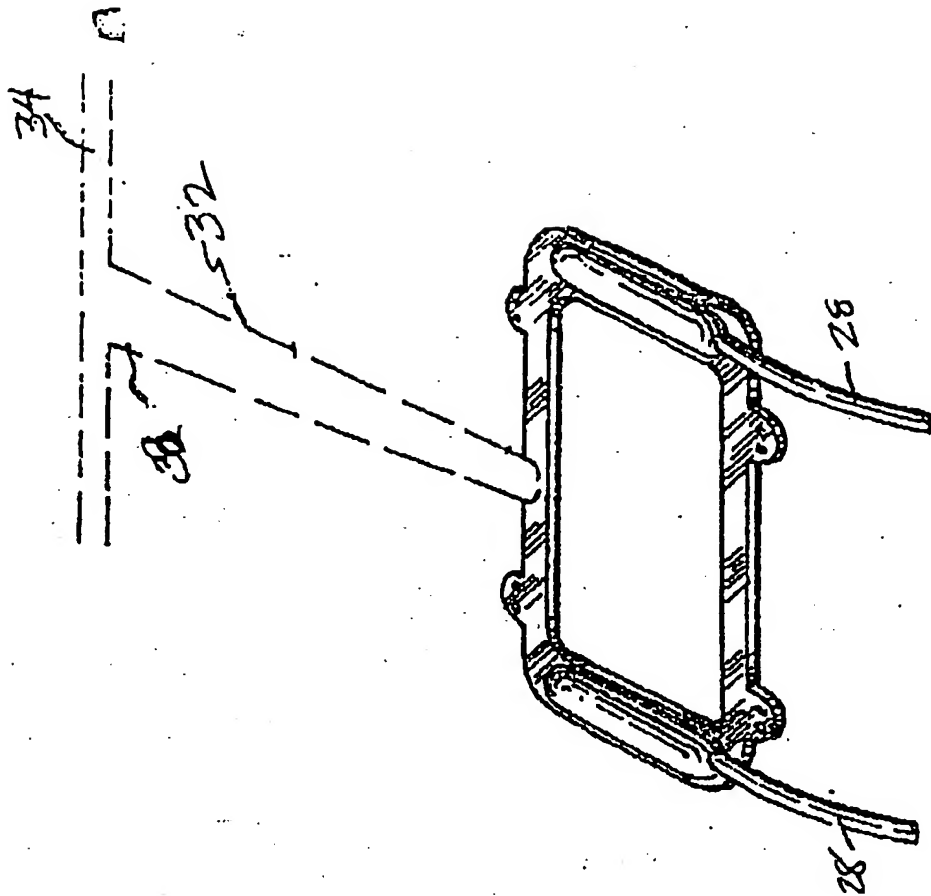


Fig. 6

Fig. 5



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# PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention EP 97 30 5596 shall be considered, for the purposes of subsequent proceedings, as the European search report

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	WO 95 17127 A (OTICON AS ; RYGAARD JOERGEN A (DK)) 29 June 1995 -----		A61B17/02 A61B17/12
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			A61B
INCOMPLETE SEARCH			
<p>The Search Division considers that the present European patent application does not comply with the provisions of the European Patent Convention to such an extent that it is not possible to carry out a meaningful search into the state of the art on the basis of some of the claims.</p> <p>Claims searched completely : 1 - 22</p> <p>Claims searched incompletely :</p> <p>Claims not searched : 23 - 26</p> <p>Reason for the limitation of the search: Method for the treatment of the human body by surgery; Article 52(4) EPC</p>			
Place of search THE HAGUE		Date of completion of the search 7 October 1997	Examiner Gérard, B
CATEGORY OF CITED DOCUMENTS		<p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p>	
<p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p>			

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